4. Other Methods for Calculating Interaction

J. T. Thomas, Oak Ridge Laboratories, has developed a neutron nonleakage fraction parameter for enriched uranium units in cuboidal arrays where experimental data for small arrays of the units in question are available or where comparable units can be interpolated from experimental data.[13] [23] His method yields critical numbers within 5 percent of experimental numbers.

H. K. Clark, by the use of simplifying assumptions, has developed a single, generally conservative method that treats the interaction of a unit as the albedo of its surroundings.[14] The albedo is determined by the neutrons emitted by other units or reflectors.

Other valuable methods for calculating critical numbers of arrays are the Monte Carlo computer codes like GEM-III[15] and KENO,[16] a simplified version of 05R. Both of these codes have been correlated with array experiments and generally are accurate to within 2 percent. GEM does not perform as well on moderated materials but KENO will handle all types. Members of the United Kingdom Atomic Energy Authority are writing a new Monte Carlo code, MONK, in Fortran to replace GEM. Monte Carlo codes will be used extensively for interaction calculations in the future.

The following table lists GEM-III and KENO calculated k_{eff} for critical experimental systems:

TABLE VIII

GEM-III AND KENO CALCULATIONS OF CRITICAL EXPERIMENTS

	k_e GEM-III	k_e KENO
Plutonium Metal Sphere, 5.6 kg ^{239}Pu[1], 19.6 g/cc, 4.0858 cm radius, 38 cm H_2O reflector	$1.004 \pm .016$	
Plutonium Metal Sphere, 4.9 kg ^{239}Pu, 19.72 g/cm, 3.9 cm radius, 20 cm H_2O reflector, $k_e = 0.97$ as calculated by DTF[18]	0.9404	
Uranium Metal Sphere, 20.11 kg ^{235}U, 19.19 g/cc, 6.3 cm radius, 20 cm H_2O reflection, $k_e = 0.98$ as calculated by DTF[18]	0.9710	

TABLE VIII (continued)

Uranium (93.2) Metal Array Experiments[19]

Unit	Mass kg U (93.2)	Diameter cm	Height cm
A^4	10.489	9.116	8.641
A^6	10.434	11.481	5.382
B^1	15.692	11.494	8.077
C^2	20.960	11.506	10.765
C^3	20.877	11.484	10.765

Subscripts on the unit designation give array size and spacing is surface-to-surface in cm.

	k_e GEM-III	k_e KENO*
A^4_{64} 4 x 4 x 4 4.625 spacing, bare	1.016 ± .016	
A^6_{64} 4 x 4 x 4 3.952 spacing, bare	1.022 ± .017	1.007 ± .008
A^6_{64} 4 x 4 x 4 12.36 spacing, 15.2 cm paraffin refl.	0.981 ± .024	
B^1_8 2 x 2 x 2 7.823 spacing, 15.2 cm paraffin refl.	0.981 ± .019	
C^2--S^1--P^2 2 x 2 x 2 5.169 spacing, C^2 ingot enclosed in a 5" Sch 40 iron pipe and each unit enclosed in a 15.6 x 15.6 x 14.8 cm box of lucite 0.64 cm thick.	1.009 ± .016	
Interacting slabs of U(93.2)O_2F_2 Solutions 79.2 g ^{235}U/l(20) One 48" x 31.5" x 6" and with a 48" x 31.5" x 3" slab perpendicular "T" shape to it but spaced 3.44" away.	0.988 ± .005	

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*Using 16 group Hansen-Roach cross sections (25).

TABLE VIII (continued)

	k_e GEM-III	k_e KENO*
Same slabs except two 3" slabs are together making two, 6" slabs both 48" x 16" x 6" in "T" shape and close together (extrapolated from experimental data).	0.946 ± .013	
4 x 4 x 4 bare array of 5 liter $U(92.6)O_2(NO_3)_2$ solution 415 g U/l[8] 10.67 cm spacing in lucite containers.	0.953 ± .017	.990 ±.010
6 x 6 x 1 bare array of 12.76 liters $U(92.6)O_2(NO_3)_2$ solution 410 g U/l[9] 14.326 cm spacing in 13 l, 5 3/8" O.D. polyethylene bottles.	0.945	
Plutonium Metal Ingot Arrays[10][11] 3.026 kgs plutonium in 6.5 cm dia. and 4.6 cm high, in 0.0371 cm thick aluminum cans, supported in aluminum tubes and with aluminum spacers and heat sinks. Polyethylene reflector blocks where used are 20.2 cm thick. In some cases 2 ingots are stacked together giving 6.05 kg.		
8, 3-kg units, 2 x 2 x 2, bare	1.017 ± .015	0.990 ± .007
27, 3-kg units, 3 x 3 x 3, polyethylene close reflection one side	0.987 ± .006	0.969 ± .009
27, 3-kg units, 3 x 3 x 3, bare		1.012 ± .011
64, 3-kg units, 4 x 4 x 4, bare	1.013 ± .019	1.006 ± .011
64, 6-kg units, 4 x 4 x 4, bare	1.008 ± .025	
64, 3-kg units, 4 x 4 x 4, bare, but each unit surrounded with 1" of mock HE	1.043 ± .024	
PuO_2 - Polystyrene and lucite blocks, isolated by 9.4 cm of polyethylene with 20 mil sheets of cadmium on each side.[21]	1.013 ± .015	

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*Using 16 group Hansen-Roach cross sections (25).

TABLE VIII (continued)

	k_e	
	GEM-III	KENO*
PuO_2 - Polystyrene Blocks, separated by layers of 1 Wt% boron stainless steel, 6" lucite reflected. Experiment No. 207A.[22]	1.030 ± 030	
Pu Metal Sphere, 5.425 Kgs ^{239}Pu, 19.74 g/cm^3 H_2O refl.[24]		1.005 ± .034

*Using 16 group Hansen-Roach cross sections[25].